Designation: B 265 – 06a

Standard Specification for Titanium and Titanium Alloy Strip, Sheet, and Plate[1]

This standard is issued under the fixed designation B 265; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification[2] covers annealed titanium and titanium alloy strip, sheet, and plate as follows:

1.1.1 *Grade 1*—Unalloyed titanium,

1.1.2 *Grade 2*—Unalloyed titanium,

1.1.2.1 *Grade 2H*—Unalloyed titanium (Grade 2 with 58 ksi minimum UTS),

1.1.3 *Grade 3*—Unalloyed titanium,

1.1.4 *Grade 4*—Unalloyed titanium,

1.1.5 *Grade 5*—Titanium alloy (6 % aluminum, 4 % vanadium),

1.1.6 *Grade 6*—Titanium alloy (5 % aluminum, 2.5 % tin),

1.1.7 *Grade 7*—Unalloyed titanium plus 0.12 to 0.25 % palladium,

1.1.7.1 *Grade 7H*—Unalloyed titanium plus 0.12 to 0.25 % palladium (Grade 7 with 58 ksi minimum UTS),

1.1.8 *Grade 9*—Titanium alloy (3.0 % aluminum, 2.5 % vanadium),

1.1.9 *Grade 11*—Unalloyed titanium plus 0.12 to 0.25 % palladium,

1.1.10 *Grade 12*—Titanium alloy (0.3 % molybdenum, 0.8 % nickel),

1.1.11 *Grade 13*—Titanium alloy (0.5 % nickel, 0.05 % ruthenium),

1.1.12 *Grade 14*—Titanium alloy (0.5 % nickel, 0.05 % ruthenium),

1.1.13 *Grade 15*—Titanium alloy (0.5 % nickel, 0.05 % ruthenium),

1.1.14 *Grade 16*—Unalloyed titanium plus 0.04 to 0.08 % palladium,

1.1.14.1 *Grade 16H*—Unalloyed titanium plus 0.04 to 0.08 % palladium (Grade 16 with 58 ksi minimum UTS),

1.1.15 *Grade 17*—Unalloyed titanium plus 0.04 to 0.08 % palladium,

1.1.16 *Grade 18*—Titanium alloy (3 % aluminum, 2.5 % vanadium) plus 0.04 to 0.08 % palladium.

1.1.17 *Grade 19*—Titanium alloy (3 % aluminum, 8 % vanadium, 6 % chromium, 4 % zirconium, 4 % molybdenum),

1.1.18 *Grade 20*—Titanium alloy (3 % aluminum, 8 % vanadium, 6 % chromium, 4 % zirconium, 4 % molybdenum) plus 0.04 % to 0.08 % palladium,

1.1.19 *Grade 21*—Titanium alloy (15 % molybdenum, 3 % aluminum, 2.7 % niobium, 0.25 % silicon),

1.1.20 *Grade 23*—Titanium alloy (6 % aluminum, 4 % vanadium with extra low interstitial elements, ELI),

1.1.21 *Grade 24*—Titanium alloy (6 % aluminum, 4 % vanadium) plus 0.04 % to 0.08 % palladium,

1.1.22 *Grade 25*—Titanium alloy (6 % aluminum, 4 % vanadium) plus 0.3 % to 0.8 % nickel and 0.04 % to 0.08 % palladium,

1.1.23 *Grade 26*—Unalloyed titanium plus 0.08 to 0.14 % ruthenium,

1.1.23.1 *Grade 26H*—Unalloyed titanium plus 0.08 to 0.14 % ruthenium (Grade 26 with 58 ksi minimum UTS),

1.1.24 *Grade 27*—Unalloyed titanium plus 0.08 to 0.14 % ruthenium,

1.1.25 *Grade 28*—Titanium alloy (3 % aluminum, 2.5 % vanadium) plus 0.08 to 0.14 % ruthenium,

1.1.26 *Grade 29*—Titanium alloy (6 % aluminum, 4 % vanadium with extra low interstitial elements, ELI) plus 0.08 to 0.14 % ruthenium,

1.1.27 *Grade 30*—Titanium alloy (0.3 % cobalt, 0.05 % palladium),

1.1.28 *Grade 31*—Titanium alloy (0.3 % cobalt, 0.05 % palladium),

1.1.29 *Grade 32*—Titanium alloy (5 % aluminum, 1 % tin, 1 % zirconium, 1 % vanadium, 0.8 % molybdenum),

1.1.30 *Grade 33*—Titanium alloy (0.4 % nickel, 0.015 % palladium, 0.02 5 % ruthenium, 0.15 % chromium),

1.1.31 *Grade 34*—Titanium alloy (0.4 % nickel, 0.015 % palladium, 0.025 % ruthenium, 0.15 % chromium),

1.1.32 *Grade 35*—Titanium alloy (4.5 % aluminum, 2 % molybdenum, 1.6 % vanadium, 0.5 % iron, 0.3 % silicon),

1.1.33 *Grade 36*—Titanium alloy (45 % niobium),

1.1.34 *Grade 37*—Titanium alloy (1.5 % aluminum), and

1.1.35 *Grade 38*—Titanium alloy (4 % aluminum, 2.5 % vanadium, 1.5 % iron).

NOTE 1—H grade material is identical to the corresponding numeric grade (that is, Grade 2H = Grade 2) except for the higher guaranteed

[1] This specification is under the jurisdiction of ASTM Committee B10 on Reactive and Refractory Metals and Alloys and is the direct responsibility of Subcommittee B10.01 on Titanium.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specifications SB-265 in Section II of that Code.

TABLE 1 Tensile Requirements[A]

Grade	Tensile Strength, min		Yield Strength, 0.2 % Offset				Elongation in 2 in. or 50 mm, min, %	Bend Test[B]	
	ksi	MPa	min		max			Under 0.070 in. (1.8 mm) in Thickness	0.070 to 0.187 in. (1.8–4.75 mm) in Thickness
			ksi	MPa	ksi	MPa			
1	35	240	20	138	45	310	24	3*T*	4*T*
2	50	345	40	275	65	450	20	4*T*	5*T*
2H[C,D]	58	400	40	275	65	450	20	...	...
3	65	450	55	380	80	550	18	4*T*	5*T*
4	80	550	70	483	95	655	15	5*T*	6*T*
5	130	895	120	828	...	...	10[E]	9*T*	10*T*
6	120	828	115	793	...	...	10[E]	8*T*	9*T*
7	50	345	40	275	65	450	20	4*T*	5*T*
7H[C,D]	58	400	40	275	65	450	20	...	...
9	90	620	70	483	...	...	15[F]	5*T*	6*T*
11	35	240	20	138	45	310	24	3*T*	4*T*
12	70	483	50	345	...	...	18	4*T*	5*T*
13	40	275	25	170	...	...	24	3*T*	4*T*
14	60	410	40	275	...	...	20	4*T*	5*T*
15	70	483	55	380	...	...	18	4*T*	5*T*
16	50	345	40	275	65	450	20	4*T*	5*T*
16H[C,D]	58	400	40	275	65	450	20	...	...
17	35	240	20	138	45	310	24	3*T*	4*T*
18	90	620	70	483	...	...	15[F]	5*T*	6*T*
19[G,H]	115	793	110	759	...	...	15	6*T*	6*T*
20[G,H]	115	793	110	759	...	...	15	6*T*	6*T*
21[G,H]	115	793	110	759	...	...	15	6*T*	6*T*
23[G,H]	120	828	110	759	...	...	10	9*T*	10*T*
24	130	895	120	828	...	...	10	...	...
25	130	895	120	828	...	...	10	...	...
26	50	345	40	275	65	450	20	4*T*	5*T*
26H[C,D]	58	400	40	275	65	450	20	...	...
27	35	240	20	138	45	310	24	3*T*	4*T*
28	90	620	70	483	...	...	15	5*T*	6*T*
29	120	828	110	759	...	...	10	9*T*	10*T*
30	50	345	40	275	65	450	20	4*T*	5*T*
31	65	450	55	380	80	550	18	4*T*	5*T*
32	100	689	85	586	...	...	10[E]	7*T*	9*T*
33	50	345	40	275	65	450	20	4*T*	5*T*
34	65	450	55	380	80	550	18	4*T*	5*T*
35	130	895	120	828	...	...	5	16*T*	16*T*
36	65	450	60	410	95	655	10	*I*	*I*
37	50	345	31	215	65	450	20	4*T*	5*T*
38	130	895	115	794	...	...	10	4*T*	5*T*

[A] Minimum and maximum limits apply to tests taken both longitudinal and transverse to the direction of rolling. Mechanical properties for conditions other than annealed or plate thickness over 1 in. (25 mm) may be established by agreement between the manufacturer and the purchaser.

[B] *T* equals the thickness of the bend test specimen. Bend tests are not applicable to material over 0.187 in. (4.75 mm) in thickness.

[C] Material is identical to the corresponding numeric grade (that is, Grade 2H = Grade 2) except for the higher guaranteed minimum UTS, and may always be certified as meeting the requirements of its corresponding numeric grade. Grade 2H, 7H, 16H, and 26H are intended primarily for pressure vessel use.

[D] The H grades were added in response to a user association request based on its study of over 5200 commercial Grade 2, 7, 16, and 26 test reports, where over 99 % met the 58 ksi minimum UTS.

[E] For Grades 5, 6 and 32 the elongation on materials under 0.025 in. (0.635 mm) in thickness may be obtained only by negotiation.

[F] Elongation for continuous rolled and annealed (strip product from coil) for Grade 9 and Grade 18 shall be 12 % minimum in the longitudinal direction and 8 % minimum in the transverse direction.

[G] Properties for material in the solution treated condition.

[H] Material is normally purchased in the solution treated condition. Therefore, properties for aged material shall be negotiated between manufacturer and purchaser.

[I] As agreed upon between purchaser and supplier.

minimum UTS, and may always be certified as meeting the requirements of its corresponding numeric grade. Grades 2H, 7H, 16H, and 26H are intended primarily for pressure vessel use.

The H grades were added in response to a user association request based on its study of over 5200 commercial Grade 2, 7, 16, and 26 test reports, where over 99 % met the 58 ksi minimum UTS.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

E 8 Test Methods for Tension Testing of Metallic Materials

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

E 120 Test Methods for Chemical Analysis of Titanium and Titanium Alloys[4]
E 190 Test Method for Guided Bend Test for Ductility of Welds
E 1409 Test Method for Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique
E 1447 Test Method for Determination of Hydrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity/Infrared Detection Method

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 Any product 0.187 in. (4.75 mm) and under in thickness and less than 24 in. (610 mm) in width is classified as strip; products 0.187 in. (4.75 mm) and under in thickness and 24 in. (610 mm) or more in width are classified as sheet; any product over 0.187 in. (4.75 mm) in thickness and over 10 in. (254 mm) in width is classified as plate.

[4] Withdrawn.

4. Ordering Information

4.1 Orders for materials under this specification shall include the following information as applicable:

4.1.1 Grade number (Section 1),
4.1.2 Product limitations (Section 3),
4.1.3 Special mechanical properties (Table 1),
4.1.4 Marking (Section 16),
4.1.5 Finish (Section 8),
4.1.6 Packaging (Section 16),
4.1.7 Required reports (Section 15), and
4.1.8 Disposition of rejected material (Section 14).

5. Chemical Composition

5.1 The grades of titanium and titanium alloy metal covered by this specification shall conform to the chemical composition requirements prescribed in Table 2.

TABLE 2 Chemical Requirements[A]

Element	Composition, %													
	Grade 1	Grade 2	Grade 2H	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 7H	Grade 9	Grade 11	Grade 12	Grade 13	Grade 14
Nitrogen, max	0.03	0.03	0.03	0.05	0.05	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Carbon, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Hydrogen,[B,C] max	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Iron, max	0.20	0.30	0.30	0.30	0.50	0.40	0.50	0.30	0.30	0.25	0.20	0.30	0.20	0.30
Oxygen, max	0.18	0.25	0.25	0.35	0.40	0.20	0.20	0.25	0.25	0.15	0.18	0.25	0.10	0.15
Aluminum	...	...	...	...	...	5.5–6.75	4.0–6.0	...	...	2.5–3.5	...	...	...	...
Vanadium	...	...	...	...	...	3.5–4.5	...	...	...	2.0–3.0	...	...	...	...
Tin	...	...	...	...	...	...	2.0–3.0	...	...	...	...	...	...	...
Ruthenium	...	...	...	...	...	...	...	...	...	...	...	...	0.04–0.06	0.04–0.06
Palladium	...	...	...	...	...	...	...	0.12–0.25	0.12–0.25	...	0.12–0.25	...	...	...
Cobalt	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Molybdenum	...	...	..	...	...	...	...	...	...	...	...	0.2–0.4	...	...
Chromium	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Nickel	...	...	...	...	...	...	...	...	...	...	...	0.6–0.9	0.4–0.6	0.4–0.6
Niobium	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Zirconium	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Silicon	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Residuals,[D,E,F] max each	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Residuals,[D,E,F] max total	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Titanium[G]	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance

Element	Composition, %												
	Grade 15	Grade 16	Grade 16H	Grade 17	Grade 18	Grade 19	Grade 20	Grade 21	Grade 23	Grade 24	Grade 25	Grade 26	Grade 26H
Nitrogen, max	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.05	0.05	0.03	0.03
Carbon, max	0.08	0.08	0.08	0.08	0.08	0.05	0.05	0.05	0.08	0.08	0.08	0.08	0.08
Hydrogen,[B,C] max	0.015	0.015	0.015	0.015	0.015	0.02	0.02	0.015	0.0125	0.015	0.0125	0.015	0.015
Iron, max	0.30	0.30	0.30	0.20	0.25	0.30	0.30	0.40	0.25	0.40	0.40	0.30	0.30
Oxygen, max	0.25	0.25	0.25	0.18	0.15	0.12	0.12	0.17	0.13	0.20	0.20	0.25	0.25
Aluminum	...	...	...	...	2.5–3.5	3.0–4.0	3.0–4.0	2.5–3.5	5.5–6.5	5.5–6.75	5.6–6.75	...	...
Vanadium	...	...	...	...	2.0–3.0	7.5–8.5	7.5–8.5	...	3.5–4.5	3.5–4.5	3.5–4.5	...	...
Tin	...	...	...	...	...	...	...	...	...	...	...	...	...

Element	Composition, %												
	Grade 15	Grade 16	Grade 16H	Grade 17	Grade 18	Grade 19	Grade 20	Grade 21	Grade 23	Grade 24	Grade 25	Grade 26	Grade 26H
Ruthenium	0.04–0.06	...	...	...	...	...	...	...	...	...	...	0.08-0.14	0.08–0.14
Palladium	...	0.04–0.08	0.04–0.08	0.04–0.08	0.04–0.08	...	0.04–0.08	...	...	0.04–0.08	0.04–0.08	...	...
Cobalt	...	...	...	...	...	...	...	...	...	...	...	...	...
Molybdenum	...	...	...	...	...	3.5–4.5	3.5–4.5	14.0–16.0	...	...	...	...	...
Chromium	...	...	...	...	...	5.5–6.5	5.5–6.5	...	...	...	...	...	...
Nickel	0.4–0.6	...	...	...	...	...	...	...	...	...	0.3–0.8	...	...
Niobium	...	...	...	...	...	...	...	2.2–3.2	...	...	...	...	...
Zirconium	...	...	...	...	...	3.5–4.5	3.5–4.5	...	...	...	...	...	...
Silicon	...	...	...	...	...	...	...	0.15–0.25	...	...	...	...	...
Residuals,[D,E,F] max each	0.1	0.1	0.1	0.1	0.1	0.15	0.15	0.1	0.1	0.1	0.1 †	0.1	0.1
Residuals,[D,E,F] max total	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Titanium[G]	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance

Element												
	Grade 27	Grade 28	Grade 29	Grade 30	Grade 31	Grade 32	Grade 33	Grade 34	Grade 35	Grade 36	Grade 37	Grade 38
Nitrogen, max	0.03	0.03	0.03	0.03	0.05	0.03	0.03	0.05	0.05	0.03	0.03	0.03
Carbon, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.04	0.08	0.08
Hydrogen,[B,C] max	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.0035	0.015	0.015
Iron, max or range	0.20	0.25	0.25	0.30	0.30	0.25	0.30	0.30	0.20-0.80	0.03	0.30	1.2–1.8
Oxygen, max or range	0.18	0.15	0.13	0.25	0.35	0.11	0.25	0.35	0.25	0.16	0.25	0.20–0.30
Aluminum	...	2.5-3.5	5.5-6.5	...	...	4.5-5.5	...	...	4.0-5.0	...	1.0-2.0	3.5–4.5
Vanadium	...	2.0-3.0	3.5-4.5	...	...	0.6-1.4	...	...	1.1-2.1	...	...	2.0–3.0
Tin	...	...	...	...	...	0.6-1.4	...	...	...	...	...	...
Ruthenium	0.08-0.14	0.08-0.14	0.08-0.14	...	...	...	0.02-0.04	0.02-0.04	...	...	...	...
Palladium	...	...	...	0.04–0.08	0.04–0.08	...	0.01-0.02	0.01-0.02	...	...	...	...
Cobalt	...	...	...	0.20–0.80	0.20–0.80	...	...	...	...	...	...	...
Molybdenum	...	...	...	...	...	0.6-1.2	...	...	1.5-2.5	...	...	...
Chromium	...	...	...	...	...	...	0.1-0.2	0.1-0.2	...	...	...	...
Nickel	...	...	...	...	...	...	0.35-0.55	0.35-0.55	...	...	...	...
Niobium	...	...	...	...	...	...	...	...	...	42.0-47.0	...	...
Zirconium	...	...	...	...	...	0.6-1.4	...	...	...	...	...	...
Silicon	...	...	...	...	...	0.06-0.14	...	...	0.20-0.40	...	...	...
Residuals,[D,E,F] max each	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Residuals,[D,E,F] max total	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Titanium[G]	balance	balance	balance	balance	balance	balance	Remainder	Remainder	Remainder	Remainder	Remainder	balance

[A] Analysis shall be completed for all elements listed in this table for each grade. The analysis results for the elements not quantified in the table need not be reported unless the concentration level is greater than 0.1 % each or 0.4 % total.

[B] Lower hydrogen may be obtained by negotiation with the manufacturer.

[C] Final product analysis.

[D] Need not be reported.

[E] A residual is an element present in a metal or an alloy in small quantities and is inherent to the manufacturing process but not added intentionally. In titanium these elements include aluminum, vanadium, tin, chromium, molybdenum, niobium, zirconium, hafnium, bismuth, ruthenium, palladium, yttrium, copper, silicon, cobalt, tantalum, nickel, boron, manganese, and tungsten.

[F] The purchaser may, in his written purchase order, request analysis for specific residual elements not listed in this specification.

[G] The percentage of titanium is determined by difference.

† Residual max value for silicon in Grade 25 was corrected editorially.

TABLE 3 Permissible Variations in Product Analysis

Element	Product Analysis Limits, max or Range, %	Permissible Variation in Product Analysis
Aluminum	0.5 to 2.5	±0.20
Aluminum	2.5 to 6.75	±0.40
Carbon	0.10	+0.02
Chromium	0.1 to 0.2	±0.02
Chromium	5.5 to 6.5	±0.30
Cobalt	0.2 to 0.8	±0.05
Hydrogen	0.02	+0.002
Iron	0.80	+0.15
Iron	1.2 to 1.8	±0.20
Molybdenum	0.2 to 0.4	±0.03
Molybdenum	0.6 to 1.2	±0.15
Molybdenum	1.5 to 4.5	±0.20
Molybdenum	14.0 to 16.0	±0.50
Nickel	0.3 to 0.9	±0.05
Niobium	2.2 to 3.2	±0.15
Niobium	>30	±0.50
Nitrogen	0.05	+0.02
Oxygen	0.30	+0.03
Oxygen	0.31 to 0.40	±0.04
Palladium	0.01 to 0.02	±0.002
Palladium	0.04 to 0.08	±0.005
Palladium	0.12 to 0.25	±0.02
Ruthenium	0.02 to 0.04	±0.005
Ruthenium	0.04 to 0.06	±0.005
Ruthenium	0.08 to 0.14	±0.01
Silicon	0.06 to 0.40	±0.02
Tin	0.6 to 3.0	±0.15
Vanadium	0.6 to 4.5	±0.15
Vanadium	7.5 to 8.5	±0.40
Zirconium	0.6 to 1.4	±0.15
Residuals[A] (each)	0.15	+0.02

[A] A residual is an element present in a metal or alloy in small quantities and is inherent to the manufacturing process but not added intentionally. In titanium these elements include aluminum, vanadium, tin, iron, chromium, molybdenum, niobium, zirconium, hafnium, bismuth, ruthenium, palladium, yttrium, copper, silicon, cobalt, tantalum, nickel, boron, manganese and tungsten.

5.1.1 The elements listed in Table 2 are intentional alloy additions or elements which are inherent to the manufacture of titanium sponge, ingot or mill product.

5.1.1.1 Elements other than those listed in Table 2 are deemed to be capable of occurring in the grades listed in Table 2 by and only by way of unregulated or unanalyzed scrap additions to the ingot melt. Therefore, product analysis for elements not listed in Table 2 shall not be required unless specified and shall be considered to be in excess of the intent of this specification.

5.1.2 Elements intentionally added to the melt must be identified, analyzed, and reported in the chemical analysis.

5.2 When agreed upon by producer and purchaser and requested by the purchaser in his written purchase order, chemical analysis shall be completed for specific residual elements not listed in this specification.

5.3 *Product Analysis*— Product analysis tolerances do not broaden the specified heat analysis requirements but cover variations between laboratories in the measurement of chemical content. The manufacturer shall not ship material that is outside the limits specified in Table 2 for the applicable grade. Product analysis limits shall be as specified in Table 3.

5.4 At least two samples for chemical analysis shall be tested to determine chemical composition. Samples shall be taken from the ingot or the extremes of the product to be analyzed.

TABLE 4 Permissible Variations in Thickness of Titanium Sheet

Specified Thickness, in. (mm)	Permissible Variations in Thickness, plus and minus, in. (mm)
0.146 to 0.1875 (3.71 to 4.76), excl	0.014 (0.36)
0.131 to 0.145 (3.33 to 3.68)	0.012 (0.31)
0.115 to 0.130 (2.92 to 3.30)	0.010 (0.25)
0.099 to 0.114 (2.51 to 2.90)	0.009 (0.23)
0.084 to 0.098 (2.13 to 2.49)	0.008 (0.20)
0.073 to 0.083 (1.85 to 2.11)	0.007 (0.18)
0.059 to 0.072 (1.50 to 1.83)	0.006 (0.15)
0.041 to 0.058 (1.04 to 1.47)	0.005 (0.13)
0.027 to 0.040 (0.69 to 1.02)	0.004 (0.10)
0.017 to 0.026 (0.43 to 0.66)	0.003 (0.08)
0.008 to 0.016 (0.20 to 0.41)	0.002 (0.05)
0.006 to 0.007 (0.15 to 0.18)	0.0015 (0.04)
0.005 (0.13)	0.001 (0.03)

6. Mechanical Properties

6.1 Material supplied under this specification shall conform to the mechanical property requirements given in Table 1 for the grade specified.

6.2 Tension testing specimens are to be machined and tested in accordance with Test Methods E 8. Tensile properties shall be determined using a strain rate of 0.003 to 0.007 in./in./min through the specified yield strength, and then increasing the rate so as to produce failure in approximately one additional minute.

6.3 For sheet and strip, the bend test specimen shall stand being bent cold through an angle of 105° without fracture in the outside of the bent portion. The bend shall be made on a diameter equal to that shown in Table 1 for the applicable grade.

7. Permissible Variations in Dimensions

7.1 Dimensional tolerances on titanium and titanium alloy material covered by this specification shall be as specified in Tables 4-13, as applicable.

8. Finish

8.1 Titanium and titanium alloy sheet, strip, and plate shall be free of injurious external and internal imperfections of a nature that will interfere with the purpose for which it is intended. Annealed material may be furnished as descaled, as sandblasted, or as ground, or both sandblasted and ground. If shipped as descaled, sandblasted, or ground, the manufacturer shall be permitted to remove minor surface imperfections by spot grinding if such grinding does not reduce the thickness of the material below the minimum permitted by the tolerance for the thickness ordered.

9. Sampling for Chemical Analysis

9.1 Samples for chemical analysis shall be representative of the material being tested. The utmost care must be used in sampling titanium for chemical analysis because of its great affinity for elements such as oxygen, nitrogen, and hydrogen. Therefore, in cutting samples for analysis, the operation should be carried out insofar as possible in a dust-free atmosphere. Chips should be collected from clean metal and tools should be clean and sharp. Samples for analysis should be stored in suitable containers.

TABLE 5 Permissible Variations in Width and Length of Titanium Sheet

Specified Width, in. (mm), for Thicknesses Under 3/16 in.	Permissible Variations in Width, in. (mm)
24 to 48 (610 to 1220), excl	+1/16 (+1.60), −0
48 (1220) and over	+1/8 (+3.20), −0
Specified Length, ft (m)	**Permissible Variations in Length, in. (mm)**
Up to 10 (3)	+1/4 (+6.35), −0
Over 10 to 20 (3 to 6)	+1/2 (+12.7), −0

TABLE 6 Permissible Variations in Weight of Titanium Sheet

The actual weight of any one item of an ordered thickness and size in any finish is limited in overweight by the following tolerance:

Any item of five sheets or less, or any item estimated to weigh 200 lb (91 kg) or less, may actually weigh as much as 10 % over the estimated weight.

Any item of more than five sheets and estimated to weigh more than 200 lb may actually weigh as much as 7½ % over the estimated weight.

There is no under tolerance in weight for titanium sheets, under tolerance being restricted by the permissible thickness variations.

Only random (or mill size) sheets may be ordered on a square foot basis, and the number of square feet shipped may exceed the number ordered by as much as 5 %.

10. Methods of Chemical Analysis

10.1 The chemical analysis shall be conducted by the standard techniques normally utilized by the manufacturer and purchaser. In case of disagreement Test Methods E 120 shall be used as the referee method except for carbon, oxygen, and hydrogen which are not covered in Test Methods E 120. Test Method E 1409 shall be used as a referee method for oxygen and Test Method E 1447 shall be used as a referee method for hydrogen.

11. Retests

11.1 If the results of any chemical or mechanical property test lot are not in conformance with the requirements of this specification, the lot may be retested at the option of the manufacturer. The frequency of the retest will double the initial number of tests. If the results of the retest conform to the specification, then the retest values will become the test values for certification. Only original conforming test results or the conforming retest results shall be reported to the purchaser. If the results for the retest fail to conform to the specification, the material will be rejected in accordance with Section 14.

12. Referee Test and Analysis

12.1 In the event of disagreement between the manufacturer and the purchaser on the conformance of the material to the requirements of this specification, a mutually acceptable referee shall perform the tests in question. The referee's testing shall be used in determining conformance of the material to this specification.

13. Rounding-Off Procedure

13.1 For purposes of determining conformance with this specification, an observed or a calculated value shall be rounded off to the nearest "unit" in the last right-hand significant digit used in expressing the limiting value. This is in accordance with the round-off method of Practice E 29.

14. Rejection

14.1 Material not conforming to the specification or to authorized modifications shall be subject to rejection. Unless otherwise specified, rejected material may be returned to the manufacturer at the manufacturer's expense, unless the purchaser receives, within three weeks of notice of rejection, other instructions for disposition.

15. Certification

15.1 If so requested by the purchaser, the manufacturer shall supply at least one copy of his report certifying that the material supplied has been inspected and tested in accordance with the requirements of this specification and that the results of chemical analysis and mechanical tests meet the requirements of this specification for the appropriate grade.

16. Marking and Packaging

16.1 *Marking*:

16.1.1 *Identification*—Unless otherwise specified, each plate, sheet, and strip shall be marked in the respective location indicated below, with the number of this specification, heat number, manufacturer's identification, and the nominal thickness in inches. The characters shall be not less than 3/8 in. (9.52 mm) in height, shall be applied using a suitable marking fluid, and shall be capable of being removed with a hot alkaline cleaning solution without rubbing. The markings shall have no deleterious effect on the material or its performance. The characters shall be sufficiently stable to withstand ordinary handling.

16.1.2 Plate, flat sheet, and flat strip over 6 in. (152 mm) in width shall be marked in lengthwise rows of characters recurring at intervals not greater than 3 in. (76 mm), the rows being spaced not more than 2 in. (51 mm) apart and alternately staggered. Heat numbers shall occur at least 3 times across the width of the sheet and at intervals not greater than 2 ft (0.610 m) along the length. As an option, when permitted, each plate, sheet, or cut length strip may be marked in at least one corner with the number of this specification, heat number, manufacturer's identification, and the nominal thickness in inches or millimetres as required.

16.1.3 Flat strip 6 in. (152 mm) and under in width shall be marked near one end.

16.1.4 Coiled sheet and strip shall be marked near the outside end of the coil.

16.2 *Packaging*—Unless otherwise specified, material purchased under this specification may be packaged for shipment either by boxing, crating, single boarding, burlapping, or with no protection in accordance with the manufacturer's standard practice.

17. Keywords

17.1 plate; sheet; strip; titanium; titanium alloys

TABLE 7 Permissible Variations in Width[A] of Titanium Strip

Specified Thickness, in. (mm)	Permissible Variations in Thickness, plus and minus, for Widths Given, in. (mm)					
	Under ½ to 3/16 (12.70 to 4.76), incl	½ to 6 (12.70 to 152.40), incl	Over 6 to 9 (152.40 to 228.60), incl	Over 9 to 12 (228.60 to 304.80), incl	Over 12 to 20 (304.80 to 508.0), incl	Over 20 to 24 (508.0 to 609.6), excl
Under 3/16 to 0.161 (4.76 to 4.09), incl	...	0.016 (0.41)	0.020 (0.51)	0.020 (0.51)	0.031 (0.79)	0.031 (0.79)
0.160 to 0.100 (4.06 to 2.54), incl	0.010 (0.25)	0.010 (0.25)	0.016 (0.41)	0.016 (0.41)	0.020 (0.51)	0.020 (0.51)
0.099 to 0.069 (2.51 to 1.75), incl	0.008 (0.20)	0.008 (0.20)	0.010 (0.25)	0.010 (0.25)	0.016 (0.41)	0.020 (0.51)
0.068 (1.73) and under	0.005 (0.13)	0.005 (0.13)	0.005 (0.13)	0.010 (0.25)	0.016 (0.41)	0.020 (0.51)

[A] These tolerances are applicable for a standard No. 3 edge.

TABLE 8 Permissible Variations in Length of Titanium Strip

Specified Length, ft (m)	Permissible Variations in Length, in. (mm)
To 5 (1.524), incl	+3/8 (+9.52), –0
Over 5 to 10 (1.524 to 3.048), incl	+½ (+12.70), –0
Over 10 to 20 (3.048 to 6.096), incl	+5/8 (+15.88), –0

TABLE 9 Permissible Variations in Thickness of Titanium Strip[A]

Specified Thickness, in. (mm)	Permissible Variations in Thickness, plus and minus, for Widths Given, in. (mm)							
	Under 1 to 3/16 (25.4 to 4.76), incl	Under 3 to 1 (76.2 to 25.4), incl	3 to 6 (76.2 to 152.4), incl	Over 6 to 9 (152.4 to 228.6), incl	Over 9 to 12 (228.6 to 304.8), incl	Over 12 to 16 (304.8 to 406.4), incl	Over 16 to 20 (406.4 to 508.0), incl	Over 20 to 24 (508.0 to 609.6), incl
Under 3/16 to 0.161 (4.76 to 4.09), incl	0.002 (0.05)	0.003 (0.08)	0.004 (0.10)	0.004 (0.10)	0.004 (0.10)	0.005 (0.13)	0.006 (0.16)	0.006 (0.16)
0.160 to 0.100 (4.06 to 2.54), incl	0.002 (0.05)	0.002 (0.05)	0.003 (0.08)	0.004 (0.10)	0.004 (0.10)	0.004 (0.10)	0.005 (0.13)	0.005 (0.13)
0.099 to 0.069 (2.51 to 1.75), incl	0.002 (0.05)	0.002 (0.05)	0.003 (0.08)	0.003 (0.08)	0.003 (0.08)	0.004 (0.10)	0.004 (0.10)	0.004 (0.10)
0.068 to 0.050 (1.73 to 1.27), incl	0.002 (0.05)	0.002 (0.05)	0.003 (0.08)	0.003 (0.08)	0.003 (0.08)	0.003 (0.08)	0.004 (0.10)	0.004 (0.10)
0.049 to 0.040 (1.24 to 1.02), incl	0.002 (0.05)	0.002 (0.05)	0.0025 (0.06)	0.003 (0.08)	0.003 (0.08)	0.003 (0.08)	0.004 (0.10)	0.004 (0.10)
0.039 to 0.035 (0.99 to 0.89), incl	0.002 (0.05)	0.002 (0.05)	0.0025 (0.06)	0.003 (0.08)	0.003 (0.08)	0.003 (0.08)	0.003 (0.08)	0.003 (0.08)
0.034 to 0.029 (0.86 to 0.74), incl	0.0015 (0.04)	0.0015 (0.04)	0.002 (0.05)	0.0025 (0.06)	0.0025 (0.06)	0.0025 (0.06)	0.003 (0.08)	0.003 (0.08)
0.028 to 0.026 (0.71 to 0.66), incl	0.001 (0.03)	0.0015 (0.04)	0.0015 (0.04)	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)	0.0025 (0.06)	0.003 (0.08)
0.025 to 0.020 (0.64 to 0.51), incl	0.001 (0.03)	0.001 (0.03)	0.0015 (0.04)	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)	0.0025 (0.06)	0.0025 (0.06)
0.019 to 0.017 (0.48 to 0.43), incl	0.001 (0.03)	0.001 (0.03)	0.001 (0.03)	0.0015 (0.04)	0.0015 (0.04)	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)
0.016 to 0.013 (0.41 to 0.33), incl	0.001 (0.03)	0.001 (0.03)	0.001 (0.03)	0.0015 (0.04)	0.0015 (0.04)	0.0015 (0.04)	0.002 (0.05)	0.002 (0.05)
0.02 (0.30)	0.001 (0.03)	0.001 (0.03)	0.001 (0.03)	0.001 (0.03)	0.001 (0.03)	0.0015 (0.04)	0.0015 (0.04)	0.0015 (0.04)
0.011 (0.28)	0.001 (0.03)	0.001 (0.03)	0.001 (0.03)	0.001 (0.03)	0.001 (0.03)	0.0015 (0.04)	0.0015 (0.04)	0.0015 (0.04)
0.010[B] (0.25)	0.001 (0.03)	0.001 (0.03)	0.001 (0.03)	0.001 (0.03)		0.001 (0.03)	0.0015 (0.04)	0.0015 (0.04)

[A] Thickness measurements are taken 3/8 in. (9.5 mm) from the edge of the strip, except that on widths less than 1 in. (25.4 mm) the tolerances given are applicable for measurements at all locations.

[B] For thicknesses under 0.010 in. (0.25 mm), in widths to 16 in. (406 mm) a tolerance of ±10 % of the thickness shall apply. In widths over 16 to 23 15/16 in. (406 to 608 mm), incl, a tolerance of ±15 % of the thickness shall apply.

TABLE 10 Permissible Variations in Weight of Titanium Strip

The actual shipping weight of any one item of an ordered thickness and width in any finish may exceed estimated weight by as much as 10 %.

TABLE 11 Permissible Variations in Width and Length[A] of Titanium Plate, Rectangular, Sheared

Specified Length, in. (mm)	Specified Width, in. (mm)	Permissible Variations Over Specified Dimension for Thicknesses Given, in. (mm)					
		Under 3/8 (9.52)		3/8 to 5/8 (9.52 to 15.88), excl		5/8 (15.88) and over	
		Width	Length	Width	Length	Width	Length
Under 120 (3048)	Under 60 (1524)	3/8 (9.52)	1/2 (12.70)	7/16 (11.11)	5/8 (15.88)	1/2 (12.70)	3/4 (19.05)
	60 to 84 (1524 to 2134), excl	7/16 (11.11)	5/8 (15.88)	1/2 (12.70)	11/16 (17.46)	5/8 (15.88)	7/8 (22.22)
	84 to 108 (2134 to 2743), excl	1/2 (12.70)	3/4 (19.05)	5/8 (15.88)	7/8 (22.22)	3/4 (19.05)	1 (25.40)
	108 (2743) or over	5/8 (15.88)	7/8 (22.22)	3/4 (19.05)	1 (25.40)	7/8 (22.22)	1 1/8 (28.58)
120 to 240 (3048 to 6096), excl	Under 60 (1524)	3/8 (9.52)	3/4 (19.05)	1/2 (12.70)	7/8 (22.22)	5/8 (15.88)	1 (25.40)
	60 to 84 (1524 to 2134), excl	1/2 (12.70)	3/4 (19.05)	5/8 (15.88)	7/8 (22.22)	3/4 (19.05)	1 (25.40)
	84 to 108 (2134 to 2743), excl	9/16 (14.29)	7/8 (22.22)	11/16 (17.46)	15/16 (23.81)	13/16 (20.64)	1 1/8 (28.58)
	108 (2743) or over	5/8 (15.88)	1 (25.40)	3/4 (19.05)	1 1/8 (28.58)	7/8 (22.22)	1 1/4 (31.75)
240 to 360 (6096 to 9144), excl	Under 60 (1524)	3/8 (9.52)	1 (25.40)	1/2 (12.70)	1 1/8 (28.58)	5/8 (15.88)	1 1/4 (31.75)
	60 to 84 (1524 to 2134), excl	1/2 (12.70)	1 (25.40)	5/8 (15.88)	1 1/8 (28.58)	3/4 (19.05)	1 1/4 (31.75)
	84 to 108 (2134 to 2743), excl	9/16 (14.29)	1 (25.40)	11/16 (17.46)	1 1/8 (28.58)	7/8 (22.22)	1 3/8 (34.92)
	108 (2743) or over	11/16 (17.46)	1 1/8 (28.58)	7/8 (22.22)	1 1/4 (31.75)	1 (25.40)	1 3/8 (34.92)
360 to 480 (9144 to 7112), excl	Under 60 (1524)	7/16 (11.11)	1 1/8 (28.58)	1/2 (12.70)	1 1/4 (31.75)	5/8 (15.88)	1 1/2 (38.10)
	60 to 84 (1524 to 2134), excl	1/2 (12.70)	1 1/4 (31.75)	5/8 (15.88)	1 3/8 (34.92)	3/4 (19.05)	1 1/2 (38.10)
	84 to 108 (2134 to 2743), excl	9/16 (14.29)	1 1/4 (31.75)	3/4 (19.05)	1 3/8 (34.92)	7/8 (22.22)	1 1/2 (38.10)
	108 (2743) or over	3/4 (19.05)	1 3/8 (34.92)	7/8 (22.22)	1 1/2 (38.10)	1 (25.40)	1 5/8 (41.28)
480 to 600 (7112 to 15 240), excl	Under 60 (1524)	7/16 (11.11)	1 1/4 (31.75)	1/2 (12.70)	1 1/2 (38.10)	5/8 (15.88)	1 5/8 (41.28)
	60 to 84 (1524 to 2134), excl	1/2 (12.70)	1 3/8 (34.92)	5/8 (15.88)	1 1/2 (38.10)	3/4 (19.05)	1 5/8 (41.28)
	84 to 108 (2134 to 2743), excl	5/8 (15.88)	1 3/8 (34.92)	3/4 (19.05)	1 1/2 (38.10)	7/8 (22.22)	1 5/8 (41.28)
	108 (2743) or over	3/4 (19.05)	1 1/2 (38.10)	7/8 (22.22)	1 5/8 (41.28)	1 (25.40)	1 3/4 (44.45)
600 (15 240) or over	Under 60 (1524)	1/2 (12.70)	1 3/4 (44.45)	5/8 (15.88)	1 7/8 (47.62)	3/4 (19.05)	1 7/8 (47.62)
	60 to 84 (1524 to 2134), excl	5/8 (15.88)	1 3/4 (44.45)	3/4 (19.05)	1 7/8 (47.62)	7/8 (22.22)	1 7/8 (47.62)
	84 to 108 (2134 to 2743), excl	5/8 (15.88)	1 3/4 (44.45)	3/4 (19.05)	1 7/8 (47.62)	7/8 (22.22)	1 7/8 (47.62)
	108 (2743) or over	7/8 (22.22)	1 3/4 (44.45)	1 (25.40)	2 (50.80)	1 1/8 (28.58)	2 1/4 (57.15)

[A] The tolerance under the specified width and length is 1/4 in. (6.35 mm).

TABLE 12 Permissible Variations from a Flat Surface for Titanium Plate, Annealed

NOTE 1—Variations in flatness apply to plates up to 15 ft (4.57 m) in length, or to any 15 ft of longer plates.

NOTE 2—If the longer dimension is under 36 in. (914 mm) the variation is not greater than 1/4 in. (6.35 mm).

NOTE 3—The shorter dimension specified is considered the width and the variation in flatness across the width does not exceed the tabular amount for that dimension.

NOTE 4—The maximum deviation from a flat surface does not customarily exceed the tabular tolerance for the longer dimension specified.

Specified Thickness, in. (mm)	48 (1219) or Under	48, excl to 60 (1219 to 1524), excl	60 to 72 (1524 to 1829), excl	72 to 84 (1829 to 2134), excl	84 to 96 (2134 to 2438), excl	96 to 108 (2438 to 2743), excl	108 to 120 (2743 to 3048), excl	120 to 144 (3048 to 3658), excl	144 (3658) and Over
3/16 to 1/4 (4.76 to 6.35), excl	3/4 (19.05)	1 1/16 (26.99)	1 1/4 (31.75)	1 3/8 (34.92)	1 5/8 (41.28)	1 5/8 (41.28)	...	...	...
1/4 to 3/8 (6.35 to 9.54), excl	11/16 (17.46)	3/4 (19.05)	15/16 (23.81)	1 1/8 (28.58)	1 3/8 (34.92)	1 7/16 (36.51)	1 9/16 (36.69)	1 7/8 (47.62)	...
3/8 to 1/2 (9.54 to 12.70), excl	1/2 (12.70)	9/16 (14.29)	11/16 (17.46)	3/4 (19.05)	15/16 (23.81)	1 1/8 (28.58)	1 1/4 (31.75)	1 7/16 (36.51)	1 3/4 (44.45)
1/2 to 3/4 (12.70 to 19.05), excl	1/2 (12.70)	9/16 (14.29)	5/8 (15.88)	5/8 (15.88)	13/16 (20.64)	1 1/8 (28.58)	1 1/8 (28.58)	1 1/8 (28.58)	1 3/8 (34.92)
3/4 to 1 (19.05 to 25.40), excl	1/2 (12.70)	9/16 (14.29)	5/8 (15.88)	5/8 (15.88)	3/4 (19.05)	13/16 (20.64)	15/16 (23.81)	1 (25.40)	1 1/8 (28.58)
1 to 1 1/2 (25.40 to 38.10), excl	1/2 (12.70)	9/16 (14.29)	9/16 (14.29)	9/16 (14.29)	11/16 (17.46)	11/16 (17.46)	11/16 (17.46)	3/4 (19.05)	1 (25.40)
Over 1 1/2 to 4 (38.10 to 101.6), excl	3/16 (4.76)	5/16 (7.94)	3/8 (9.54)	7/16 (11.11)	1/2 (12.70)	9/16 (14.29)	5/8 (15.88)	3/4 (19.05)	7/8 (22.22)
Over 4 to 6 (101.6 to 152.4), excl	1/4 (6.35)	3/8 (9.54)	1/2 (12.70)	9/16 (14.29)	5/8 (15.88)	3/4 (19.05)	7/8 (22.22)	1 (25.40)	1 1/8 (28.58)

TABLE 13 Permissible Variations in Thickness for Titanium Plate

Specified Thickness, in. (mm)	Width, in. (mm)[A]			
	To 84 (2134), incl	Over 84 (2134) to 120 (3048), incl	Over 120 (3048) to 144 (3658), incl	Over 144 (3658)
	Tolerances Over Specified Thickness, in. (mm)[B]			
0.1875 (4.76) to 0.375 (9.52), excl	0.045 (1.14)	0.050 (1.27)	...	...
0.375 (9.52) to 0.750 (19.05), excl	0.055 (1.40)	0.060 (1.52)	0.075 (1.90)	0.090 (2.29)
0.750 (19.05) to 1.000 (25.40), excl	0.060 (1.52)	0.065 (1.65)	0.085 (2.16)	0.100 (2.54)
1.000 (25.40) to 2.000 (50.80), excl	0.070 (1.78)	0.075 (1.90)	0.095 (2.41)	0.115 (2.92)
2.000 (50.80) to 3.000 (76.20), excl	0.125 (3.18)	0.150 (3.81)	0.175 (4.44)	0.200 (5.08)
3.000 (76.20) to 4.000 (101.6), excl	0.175 (4.44)	0.210 (5.33)	0.245 (6.22)	0.280 (7.11)
4.000 (101.6) to 6.000 (152.4), excl	0.250 (6.35)	0.300 (7.62)	0.350 (8.89)	0.400 (10.16)
6.000 (152.4) to 8.000 (203.2), excl	0.350 (8.89)	0.420 (10.67)	0.490 (12.45)	0.560 (14.22)
8.000 (203.2) to 10.000 (254.0), incl	0.450 (11.43)	0.540 (13.72)	0.630 (16.00)	...

[A] Thickness is measured along the longitudinal edges of the plate at least ⅜ in. (9.52 mm), but not more than 3 in. (76.20 mm), from the edge.

[B] For circles, the over thickness tolerances in this table apply to the diameter of the circle corresponding to the width ranges shown. For plates of irregular shape, the over thickness tolerances apply to the greatest width corresponding to the width ranges shown. For plates up to 10 in. (254.0 mm) incl. in thickness, the tolerance under the specified thickness is 0.010 in. (0.25 mm).

SUPPLEMENTARY REQUIREMENTS

These requirements shall apply only when specified in the purchase order, in which event the specified tests shall be made by the manufacturer before shipment of the plates.

S1. Surface Requirement Bend Tests

S1.1 The purpose of this test is to measure the cleanliness or ductility, or both, of the metal surface.

S1.2 Two guided- or free-bend tests of sheet or plate material limited to the grades listed in S1.4. Each of these bends will place opposite surfaces of the sheet or plate material in tension.

S1.3 The bends are to be made in accordance with Test Method E 190 or Method E 16, except that the welds mentioned in these standards are not required. The bend specimen may be of less than full material thickness; however, the outer surface of the specimen must be representative of the product as supplied.

S1.4 The bend radius will be such to provide minimum elongation of the outer fibers of the bent specimen as follows:
Grade 1—20 % equivalent to 2T bend radius at 180° bend,
Grade 2—20 % equivalent to 2T bend radius at 180° bend,
Grade 2H—20 % equivalent to 2T bend radius at 180° bend,
Grade 3—16 % equivalent to 2½ T bend radius at 180° bend,
Grade 7H—20 % equivalent to 2T bend radius at 180° bend,
Grade 16H—20 % equivalent to 2T bend radius at 180° bend,
Grade 26H—20 % equivalent to 2T bend radius at 180° bend.

S1.5 Criteria for acceptance will be the absence of any cracking or surface separations (not originating at the edge of specimen).

S2. Alternate Yield Strength Maximum

S2.1 Maximum yield strength (0.2 % Offset) of Grade 1, 11, 17, or 27 shall be limited to 40 ksi (275 MPa).

S3. Special Flatness Requirements

S3.1 These requirements apply only for material to be used for explosive cladding.

S3.2 These requirements apply only to Grades 1, 11, 17, and 27 and only in thickness ranging from 0.078 to 0.78 in. (2.0 to 20 mm), inclusive.

S3.3 The overall out-of-flatness shall be no greater than 50 % of that permitted in Table 12.

S3.4 Localized out-of-flatness shall be no greater than 0.12 in. (3.0 mm) deviation from a 39 in. (1000 mm) long straight edge when placed at any location on the plate surface. When the straight edge is placed on a single high point, the maximum deviation from the plate at each end shall be no greater than 0.12 in. (3.0 mm).